Report No. 5300-71-20
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LEAK DETECTION WITH EXPANDABLE COATINGS

Final report on Contract NAS 8-26761
Control No. DCN 1-1-60-0010 (IF)

February 19 to December 18, 1971

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N O T I C E

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by

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Abstract

Objective of this study was to develop and evaluate a system for leak detection that could be easily applied over separable connectors and that would expand into a bubble or balloon if a leak were present. This objective was accomplished using thin films of Parafilm tape wrapped over connectors, which were then overcoated with a special formulation. The low yield strength and the high elongation of the envelope permit bubble formation if leakage occurs. This system may be appropriate for welds and other hardware besides separable connectors. The practical limit of this system appears to be for leaks exceeding 10^{-6} cc/sec. If this envelope is used to trap gases for mass spectrometer inspection, leaks in the range of 10^{-8} cc/sec. may be detectable.

FOREWORD

This report was prepared by Hauser Laboratories under contract NAS 8-26761 for the George C. Marshall Space Flight Center of the National Aeronautics and Space Administration. The work was administered under the technical direction of the Quality & Reliability Assurance Laboratory of the George C. Marshall Space Flight Center.

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I. INTRODUCTION

All missiles using liquid propellants have a large amount of piping using separable connectors. Each separable connector is a potential cause of leakage, and any leakage can be a serious malfunction. Rapid and sensitive detection of leaks at such connectors is thus a major concern for proper quality assurance and missile reliability.

Use of expandable coatings over separable connectors is a novel approach to the problem of leak detection, and this study was aimed toward developing materials appropriate for this purpose. The objective was to develop a system of coating/adhesive/release materials which could be tightly conformed over a separable connector and which would then form blisters or bubbles if the joint were to leak when pressurized. This blister or bubble should then be easily identified as a leakage point, and the material should be easily removable from the connector after tests have been completed.

II. CONCEPTS

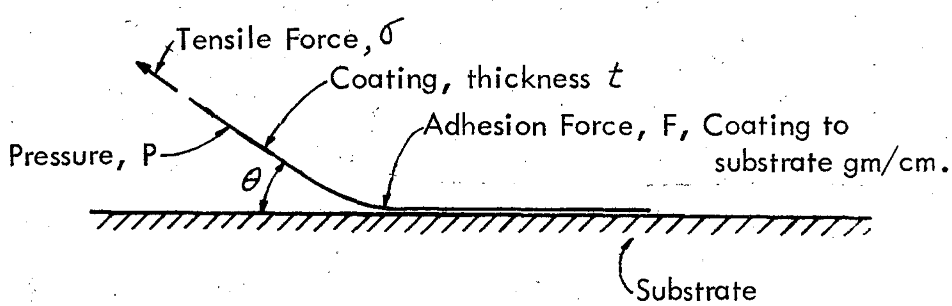
In many respects, the ideal material for this leak detecting coating would be a solid-phase soap bubble -- a material that could be painted on easily, and that would deform easily when pressurized. But unlike a soap bubble, the material would have long-term durability for tests that might last for at least several hours.

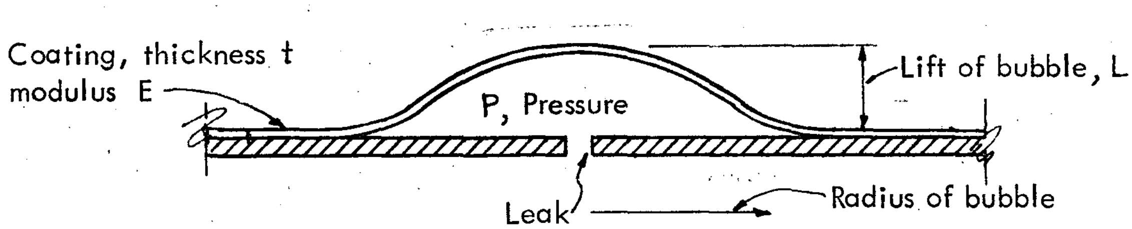
The mechanical properties of this ideal material would include low yield strength (in biaxial tension) and very high elongation (again biaxial tension) prior to rupture or pinhole formation.

Application properties of the ideal material would include opportunity for easy brushing over the connectors, rapid drying, and almost impossible flow characteristics -- smooth, uniform coverage over rough surfaces such as pipe threads and the ability to not flow into cracks and crevices.

Although a lifting and expanding balloon is hardly a "structure" some stress analysis has provided an understanding of the coating/hardware interface adhesion problems. This analysis relates to the yield strength of the film and its peel adhesion bond to the hardware.

The bubble lifting geometry can be simplified in two dimensions as:





Williams [1] describes the relations of bubble pressure, radius, and lift in relation to coating thickness and modulus of elasticity as follows:

$$r = \left(\frac{64\ L\ E\ t^3}{9\ P} \right)^{0.25}$$

(1) Williams, M. L., "The Continuum Interpretation for Fracture and Adhesion." J. Applied Polymer Science, vol. 13, 29-40, (1969).

The equation is applicable only for a very small amount of lift, and this condition truly exists if there is no transition in the adhesion of coating to substrate. Once pressure P has caused L to become finite, r has a finite value. The flatwise radius of the bubble can be maintained at a pressure less than the initial lifting pressure (since P is in the denominator of the above equation). In other words, the condition is unstable -- if lift is initiated, r will continue increasing until the edge of the coating is reached, and then the bubble will leak at its edges.

This analysis underscores the importance of having a demarcation in the adhesion of coating to substrate -- a higher peel strength at the edges where seal is to be maintained than at the leak area where the bubble is expected to lift.

If the tensile force on the bubble (at any angle θ) exceeds the adhesion bond (at the same angle) of coating to substrate, the coating will lift slightly, leak at its edges and fail to indicate a leaking connector.

In order for the bubble to maintain its seal and grow by stretching, the yield strength of the bubble material must be low in relation to its adhesion peel strength to the substrate. This requirement is expressed mathematically as:

$$\sigma_y < F/t$$

where σ_y = tensile yield strength of the coating, gm/sq. cm

F = adhesion to substrate gm/cm

t = coating thickness, cm

In order to obtain this demarcation in adhesive bond to the substrate, two combinations of materials can be used:

a. A release material placed under the coating in the areas where ballooning is desired, and a coating with fair adhesion to the substrate.

b. a coating with poor adhesion (easy release) to the substrate and a separate adhesive material applied at the interface where the bubble seal is desired.

Both concepts in materials combinations have been studied on this contract.

III. FORMULATIONS & APPLICATION PROPERTIES

Coatings, releases and adhesive materials were studied independently and then they were tested in combination for leakage performance tests. Major emphasis was given to the coatings.

A. Coating Materials

A large number of coating materials were considered, many were tried, and a few were tested. These studies started with some materials on the laboratory shelves and the scope was expanded as time and search indicated other prospects.

Thermoplastic elastomers and plasticized vinyl resins were the main emphasis in materials selection and formulation. The block copolymer of styrene and butadiene (Shell Kraton rubber) and thermoplastic urethanes were known to have high elongation and relatively high creep characteristics. Whereas the creep or viscous component of these polymers is often excessive

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for mechanical applications, these elastomers were much too elastic by themselves and required a fair amount of modification with waxes and plasticizers.

An expanding bubble toy has intriguing characteristics pertinent to this study, and "Super Elastic Bubble Plastic" was given some consideration. Infra-red spectral analysis revealed that this material was a vinyl acetate polymer. Whereas the material expands easily into an air-blown bubble, it quickly loses its solvent and forms a relatively hard, non-tacky bubble. Reformulation with permanent plasticizers rather than solvent might provide a practical expandable coating. Several vinyl formulations were prepared following recommendations of Union Carbide Corporation, Diamond-Shamrock Corporation and others.

Special additives were sometimes used to modify the surface tackiness, coating/substrate adhesion, flow characteristics or appearance. NP Antidust was used mostly as an anti-tack, and Zelec UN was used as an internal release additive to decrease the substrate adhesion of coatings.

A total of 136 formulations were outlined, as noted in Table 1, page 17. As each formulation was prepared, the application characterisitics were noted quantitatively and some adjustments were made immediately. Quick screening tests were frequently made to learn whether a good film was formed, and whether the coating had attractive properties of elongation and adhesion or release.

If the coating looked like a good prospect, its viscosity, tack time and dry time were measured. First viscosity tests were made with a Shell #2 viscosimeter, but most coatings were too viscous or dried (and plugged) too fast for this instrument. Shell #4 cup was used for most viscosity tests.

These application properties are noted in Table 1 along with the formulations. The number-coded suppliers of materials (except some common laboratory solvents and pigments) are noted in Table 2, page 39.

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A number of parametric studies were made after good prospects had been identified. Four of these studies used Kraton elastomers with different amounts or types of wax or plasticizer additives. Figure 1, page 55 shows the effects of a polypropylene wax added to Kraton 1101. Figure 2, page 56 shows the very desirable attributes obtained by addition of Chlorowax 70 to Kraton 1101. Four plasticizers were then compared for the Kraton/Chlorowax 70 system in Figure 3, page 57 . Finally the two alternative Kraton elastomers were compared with Kraton 1101 in Figure 4, page 58 . All these studies used quantitative mechanical properties for comparison as follows:

Stress at 50% elongation
Permanent set after 50% elongation
Ultimate tensile strength
Ultimate elongation
Tear strength
90° peel adhesion strength

Details for these tests are discussed below in Paragraph IV-A.

A similar set of parametric studies was performed for the Bakelite VYHH vinyl resin with a variety of plasticizers and waxes. These data are shown in Figure 5, page 59 .

Formula 105 was one of the best coatings of the study, and several variations were made therefrom. Dyes, Day-Glo pigments and solvents varied until Formula 130 was considered to provide the best combination of application and performance characteristics.

Subsequent formulations combining the coating in an aerosol with Propellant #12 indicated feasibility for spray application, but this alternative was not pursued to optimization.

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B. Release Materials

Ten different tape and coating type releases were evaluated in this program, as outlined in Table 3, page 40 .

The tapes were selected for ready conformability to the geometry of separable connectors. The self-vulcanizing silicone tape formed an excellent seal and release from the hardware, but coatings usually bonded to the silicone tape and reacted in an elastic manner because of the tape elasticity. The Teflon tape gave good release from both the hardware and the coating, but edges of this tape were too sharp and coatings were cut at these points.

None of the paint-on release materials was adequate. A greasy or non-wetting surface caused difficulties in the subsequent coating operation.

The best release material was Parafilm tape in 2-3 mil thickness. Parafilm is a waxy film that has high plastic elongation and a very low yield strength. When this material was used as a release tape, it could be stretched easily and then conformed tightly to the separable connector. Overcoats of the coating formulation bonded to the Parafilm, and the coating solvents helped to seal together the edges of the Parafilm. Parafilm and overcoating deformed together during pressurization, discussed below in Paragraph V-C.

The commercial Parafilm tape is produced in 5-mil thickness. Laboratory samples of 2-3 mil Parafilm were made by stretching the film about 100% between two sets of rollers. Delivery samples were made by the manufacturer, American Can Company, in a special production run.

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C. Adhesive Materials

Seven adhesives were tried, as noted in Table 4, page 41 . These adhesives were used only with coatings that had good release characteristics. Final formulations had adequate adhesion of coating to substrate and no adhesive was used in the final leak detection system.

The double tacky tape was ineffective when placed on hex nuts, due to lifting at the sharp bends. Otherwise each of the adhesives could be used with the appropriate type of coating (e.g. vinyl adhesive for vinyl coating and rubber adhesive for rubber coating).

IV. MECHANICAL PROPERTIES OF COATINGS

Pertinent tests were performed to evaluate in quantitative terms the mechanical properties of coatings. Test methods, results and selection criteria are discussed below.

A. Coating Selection Criteria

Tests were selected to identify those characteristics of the coatings that were most important in performance of leak detection objectives. Properties of low yield strength and high plastic elongation were considered to be essential. High tensile and tear strength would be helpful. Low or moderate peel adhesion strength would be needed, respectively, for a release coating or for an adherent coating. Tests and criteria are outlined below:

1. Tensile stress at 50% elongation.

   Bubbles or blisters with 50% stretch of the film would be easily identified. A low stress at this elongation would signify low yield strength and easy distension of the bubble, preferably less than 30 Kg/sq.cm.

2. Permanent set after 50% elongation.

After the film has been stretched 50% and the load or pressure is decreased to zero, the film should not return in an elastic manner to original dimensions. A high permanent set would be desirable, preferably exceeding 50% of the stretch.

3. Ultimate tensile strength of the film may be of some significance, particularly in relation to toughness and durability during handling. A moderate ultimate tensile strength might provide a fair balance of durability and ease of removal. Strength between 1 and 30 Kg/sq.cm. was considered appropriate.

4. Ultimate elongation of the coating film was desired to be as high as possible, commensurate with other attributes. Elongation of 200% was considered to be the minimum acceptable.

5. Tear strength was desired to be a maximum, for best durability of the coating. This characteristic was considered secondary to the extensible properties noted above.

6. Peel adhesion was desired to be below 100 gm/cm for use as a release coating and above $\sigma_y t$ gm/cm if the coating was to be its own adhesive. As in Par. II above, $\sigma_y t$ is the product of the film yield strength and the film thickness.

B. Test Methods

The coating formulations were painted onto a release surface in order to obtain free films for testing. In most cases, polyethylene was used as the release surface, but with many of the Kraton/Chlorowax formulations no good adhesive surface was found. For these coatings, heavy paper was sized with animal glue prior to brush coats of the test formulation. Free films were then obtained by soaking the paper in water.

Tensile and tear test specimens were die-cut from these films. The tensile tests used specimens described in ASTM D412 and tests were performed at the rather slow crosshead speed 5 cm/minute (2 inches per minute). This permitted the operator to stop the test at the first 50% elongation, reverse the crosshead to learn

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permanent set and then continue the test to learn ultimate strength and ultimate elongation. The force and crosshead position were recorded continuously during these tests.

Tear strength tests were performed according to ASTM D624, die C with crosshead a rate of 5 cm/minute (2 inches/minute). The maximum tear force was recorded, per unit of specimen thickness.

The peel adhesion specimens were made by coating a stainless steel coupon 2.5 cm x 15 cm with two coats of the formulation. Then a cotton tape was placed onto one end of the coating and two more coats were applied. The tape was pulled at 90° angle to the stainless steel coupon at a rate of 5 cm/minute (2 inches/minute) and force was recorded continuously. Average peeling force per unit width was reported.

C. Results of Mechanical Tests

Coatings were tested with three replicate specimens and averages are reported in Table 5, page 45 . Some of these data were discussed above in Figures 1-5.

As might be expected, this wide variety of coatings had properties that ranged from cheesy and sleazy to rough and tough. Some of the highly plasticized vinyl coatings would hardly support the weight of the dumb-bell shaped test specimen.

The properties of Formula #130, the recommended coating, are noted below:

Strength at 50% elongation	1.35 Kg/sq.cm
Permanent set after 50% elongation	53%
Ultimate tensile strength	1.61 Kg/sq.cm
Ultimate elongation	860+%
Tear strength	1.66 Kg/sq.cm
Peel strength	47.4 gm/cm (peel after yielding)

Parafilm is another component of the recommended leak detection system and its properties are:

Strength at 50% elongation	27.7 Kg/sq.cm.
Permanent set after 50% elongation	87%
Ultimate tensile strength	27.7 Kg/sq.cm.
Ultimate elongation	200%
Tear Strength	22.3 Kg/sq.cm.

V. PERFORMANCE TESTS

Tests were prepared to simulate the performance of the leak detection systems. These tests used separable connectors with the detection systems applied thereupon.

A. Performance Test Apparatus

Six sets of ten separable connectors were prepared using 1/2-inch stainless tubing with flare and flareless connectors. Each connection was mutilated with a groove by a triangular file so that it would leak. The ten connections were assembled with a quick disconnect fitting to provide rapid assembly for pressurization.

To evaluate the opportunity of handling different sizes of separable connectors, two additional "Christmas trees" were prepared using tubes of diameter 1/8 to 1" and a variety of step adapters. These also had a quick disconnect fitting for pressurization.

Air was used for pressurization of these test units, and a pressure regulator/ gauge combination was used at the unit. This permitted gradual increase in pressure for each test.

Perfor

Performance tests were normally performed with the connectors under water, Figure 6, page 60. If air bubbles were observed without an obvious distension of the coating, the leak detector was faulty. If distension was observed, a pinhole or burst failure would usually follow, and then bubbles would be observed. If neither distension nor air bubbles were noted, the coating system had closed off the leak. Sometimes this could be opened up at higher pressures (60 psi was the maximum pressure used), but if no leakage was obtained, the connector was considered to be "no test".

B. Application of Leak Detection Systems

First tests of the coatings were made by brushing or taping the appropriate release and/or adhesive and then by brushing on the extensible coating usually using two coats. The coating was allowed to dry overnight and then it was tested under water as noted above.

The number of distended bubbles or blisters and the number of leaking fittings were noted for each leak detection system. The lift distance was also noted for each bubble or blister.

As the detection systems developed, the combination of an extensible release tape and an extensible coating looked more and more attractive. The recommended system uses 3-mil Parafilm as a release tape and coating #130 as an overcoat.

The materials used for the recommended system consist of the following:

Parafilm tape, 3-mil thick by 1.5 cm wide by 8-10 cm long.
Tape tightener -- a bundle of 10-15 elastic threads 20 cm. long, made of #600 Nylon elastic threads (Scoville Dritz)
Expandable coating, formula #130
Artists paint brush, #49 Fitch Fan

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Figure 7, page 61 illustrates the four steps for application of the leak detection system:

A. A strip of Parafilm tape is pulled tightly against the tubing at one edge of the separable connector at least 2 mm beyond threads, insert or nut. The short end of the tape is pulled tightly against the tube and then it is folded toward the nut. The first wrap of the tape covers this short end.

B. The tape is wrapped around nut and threads, pulled tightly into a helical pattern with at least 3 mm overlap for each turn. The tape is pulled tightly as it makes the transition between nut and thread diameter. Tape is terminated at a distance 3-4 mm beyond the last thread or insert. Termination is accomplished by stretching the Parafilm tape and breaking it at the tube.

   The Parafilm tape wrap is now inspected to insure that a complete "mummy wrap" exists with no holidays.

C. Void volume within the Parafilm tape wrap must be minimized. To do this, the bundle of elastic threads is wrapped around the fitting at threads, inserts, bridges, or any place where the film is not in close contact with the hardware.

   The tape wrap is again inspected to insure that complete, void-free envelope.

D. A smooth brush coat of the coating #130 is applied over the Parafilm tape, extending 2-3 mm onto the tubing or fitting. After a 2-3 hour dry, a second brush coat of #130 is applied.

   After the coating has dried 12-16 hours it should be inspected to insure that complete coverage has been obtained and to insure that the edges of the Parafilm tape have been sealed by the coating.

E. During or after system pressurization, the expanded bubble is inspected by both visual and tactile senses. If the bubble is not obvious, a finger can discern whether the film has lifted from the hex nut of the separable connector.

C. Results of Performance Tests

About 500 connectors were coated with various combinations of releases, adhesives and expandable coatings. Results of these tests are presented in Table 6, page 49 .

In this table, the fraction of identifiable leaks (balloon bubbles) and the lift distance for these bubbles are the measures of performance.

Coating #130 with release #B10 provided the best and most consistent leak detection performance. Application of this system was described above. Bubbles were readily discerned in 105 of the 107 separable connectors where it was applied. Insufficient coverage of the coating #130 was cause for nondetection in the two tests, and insufficient inspection was cause for nondetection of the coverage. This was due to a violation of Quality Control Commandment #1 -- "The operator and the inspector shall be different persons responsible to different authorities."

Coating #134 was applied by aerosol over Parafilm tape, release B10, and it was effective in 7 of 9 connectors. This indicated the feasibility of aerosol application, but #134 was probably not an optimum formulation.

D. Reliability and Sensitivity of Leak Detection Systems

The recommended leak detection system described above appears to be highly reliable for large leaks when applied and inspected properly.

The smallest of the 107 leaks was measured to pass air at the rate of 2×10^{-4} cc/sec. (measured by water displacement). This leak was easily discernible with the expandable coating within a period of 1 hour.

Gas transmission rate of the Parafilm/#130 coating system was measured as 2670 cc/sq. meter 24 hr. atm. Since the coating over a hex nut of 0.5" diameter requires only 360 gm/sq.cm. or 5.1 psi pressure to cause yielding and ballooning, the permeation pressure can not exceed this value. Thus the leak detection limit of this system is in the range of 7×10^{-7} cc/sec. The practical time limit of this system may be somewhere in the range of 10^{-6} cc/sec. over a period of 24 hour pressurization (0.1 cc. accumulation).

A further improvement is obvious in the area of application inspection. Since two coats of formula #A130 are used, the first coating would be better with an opaque white pigment and the second coating would be better with the Day-Glo pigment. This would provide an extra opportunity for inspecting the rather critical aspect of complete coverage by the coatings.

This leak detection system may be valuable in combination with mass spectrometer methods for extremely sensitive inspection. The envelope provided by this system could entrap the gases from a minute leak, and a hypodermic needle probe inserted into the envelope could identify the accumulation of this leakage. Such a system may be sensitive to 10^{-8} cc/sec. leak rate. Concern should be given to make sure that coating plasticizers do not interfere with the inspection system.

E. Removal of Leak Detection Systems

The unbonded portion of the leak detection wrapping is easily removed. A fingernail easily pierces the coating and the material pulls off cleanly. At the end where the coating is bonded onto the tubing, a rubbing action is needed to remove the formulation. Alternatively or additionally, a wipe with a solvent-moistened cloth quickly dissolves the residue. Toluene or trichloroethylene may be used as the solvent, depending upon concerns of flammability and vapor toxicity.

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VI. CONCLUSIONS

Contract requirements have been met in the development and evaluation of an expandable coating system for leak detection. The system has not yet been evaluated in actual or simulated missile hardware to learn the practicality of application and the time/cost/reliability/sensitivity comparisons with alternative leak detection systems.

Coating #130 with 3-mil Parafilm tape provides an expandable coating system of leak detection that is sensitive to less than 10^{-6} cc/sec. leakage rate. It is readily visible and easily inspected for detection of leaks by visual and tactile senses. It is easily removable after use. In conjunction with a mass spectrometer, this system might provide 10^{-8} cc/sec. sensitivity.

Although the leak detection system was directed toward application on separable connectors, it may also have considerable utility for leak inspection of welds and other hardware. Slight modification of the tape/coating system could provide "band-aid" simplicity in application of leak detection patches.

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Table 1 - Formulas and Application Properties of Coatings

			Supplier	Viscosity seconds	Tack Time minutes	Dry Time minutes
A1	RTV 102	20	15			
	Silicone grease	10	11		Not Tested	
	Freon TF	35	13			
	Ethylene dichloride	6.4				
A2	Parafilm	30	17	too viscous (#2)	3+ hrs.	19+ hrs.
	Zelec UN	0.5	13			
	Freon TF	35	13			
	Ethylene dichloride	235				
A3	R170857	3	14		Not Tested	
	Freon TF	17.5	13		Incompatible mixture	
	Ethylene dichloride	17.5				
A4	Coverlac A-1114		22		Not Tested	
A5	H P Latex				Not Tested	
A6	Spraylat SC-1073		22		Not Tested	
A7	Estane 5711	20	2			
	Vaseline	5				
	Zelec UN	0.1	13		Not Tested	
	Freon TF	25	13			
	Acetone	35				
	Ethylene dichloride	45				
A8	Kraton 1101	20	21		Not Tested	
	Zelec UN	0.2	13			
	Freon TF	65	13			
	Ethylene dichloride	65				
A9	Kraton 1101	20	21		Not Tested	
	Vaseline	5				
	Zelec UN	0.2	13			
	Freon TF	70	13			
	Ethylene dichloride	70				

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Table 1 - Formulas (Cont.)

			Supplier	Viscosity seconds	Tack Time minutes	Dry Time minutes
A10	Hypalon 30	50	13	too viscous (#2)	2.5	6.5
	PPO #691-111	6	15			
	Modaflow	0.25	18			
	Titania	60				
	G 6099 Green	6	6			
	Trichloroethylene	218				
A11	#11444 Tacki-wax	20	5	too viscous (#2)	14.5	18+ hrs.
	Vaseline	5				
	Zelec UN	0.2	13			
	Freon TF	45	13			
	Ethylene dichloride	45				
A12	Chlorowax 70	20	10	too viscous (#2)	48	2.5+ hrs.
	Freon TF	30	13			
	Ethylene dichloride	40				
A13	Epolene X3259-11B	20	12		Not Tested	
	Freon TF	65	13			
	Ethylene dichloride	65				
A 14	Epolene X3259-11C	20	12		Not Tested	
	Freon TF	40	13			
	Ethylene dichloride	40				
A15	Coverlac SC-271		22		Not Tested	
A16	Goodrich latex 60-457		2		Not Tested	
A17	RTV 102	10	15	too viscous	90+	120+
	Silicone grease	10	11			
	Zelec UN	0.5	13	(#2)		
	Freon TF	20	13			
	Ethylene dichloride	10				

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Table 1 - Formulations (Cont.)

			Supplier	Viscosity seconds	Tack Time minutes	Dry Time minutes
A18	Spraylat SC-1073	20	22	too viscous	20	29
	Epon 828	2	21			
A19	Estane 5711	20	2	too viscous (#2)	3	60
	Vaseline	5				
	Zelec UN	0.1	13			
	Paint Additive #7	0.05	11			
	Freon TF	25	13			
	Acetone	35				
	Ethylene dichloride	45				
A20	Kraton 1101	20	21	too viscous (#2)	13	33
	Zelec UN	0.2	13			
	Paint Additive #7	0.07	11			
	Freon TF	65	13			
	Ethylene dichloride	65				
A21	Coverlac SC-271	20	22		Not Tested	
	Epon 828	2	21			
A22	Estane 5711	20	2		Not Tested	
	Epon 828	4	21			
	Freon TF	24	13			
	Acetone	35				
	Ethylene dichloride	45				
A23	Kraton 1101	20	21	too viscous (#2)	1	29
	Epolene X3259-11C	10	12			
	Zelec UN	0.2	13			
	Freon TF	70	13			
	Ethylene dichloride	70				

Table 1 - Formulations (Cont.)

	Ingredient	Amount	Supplier	Viscosity seconds	Tack Time minutes	Dry Time minutes
A24	Kraton 1101	20	21	too viscous (#2)	2	32
	Vaseline	10				
	Zelec UN	0.2	13			
	Paint Additive #7	0.14	11			
	Freon TF	65	13			
	Ethylene dichloride	65				
A25	Chlorowax 70	50	10	too viscous	56	7+ hrs.
	Trichloroethylene	25				
A26	Kraton 1101	10	21		Not Tested	
	Epolene X3259-11C	5	12			
	Zelec UN	0.1	13			
	Trichloroethylene	100				
A27	Kraton 1101	10	21	too viscous (#2)	2	70+
	Vaseline	5				
	Zelec UN	0.1	13			
	Paint Additive #7	0.07	11			
	Trichloroethylene	65				
A28	Estane 5711	10	2		Not Tested	
	Vaseline	2.5				
	Zelec UN	0.05	13			
	Paint Additive #7	0.025	11			
	Trichloroethylene	35				
	Acetone	17.5				
A29	Spraylat 1073	20	22	too viscous	18	37
	Day-Glo D13	1	9			
A30	Kraton 1101	10	21		Not Tested	
	Epolene	7.5	12			
	Zelec UN	0.1	13			
	Trichloroethylene	75				

Table 1 - Formulations (Cont.)

			Supplier	Viscosity seconds	Tack Time minutes	Dry Time minutes
A31	Kraton 1101	10	21			
	Chlorowax 70	5	10		Not Tested	
	Vaseline	5				
	Zelec UN	0.1	13			
	Paint Additive #7	0.1	11			
	Trichloroethylene	50				
A32	Estane 5711	10	2	too viscous	114	6.5+ hrs.
	Epolene X3259-11C	5	12			
	Vaseline	5				
	Zelec UN	0.1	13			
	Paint Additive #7	0.1	11			
	Acetone	20				
	Trichloroethylene	40				
A33	Spraylat SC-1073	30	22	Not Tested	14	26
	Day-Glo D13	0.5	9			
A34	Spraylat SC-1073	60	22	too viscous (#2)	20	44
	Day-Glo D13	1	9			
	Dioctyl phthalate	4				
A35	Parafilm	15	17			
	Toluene	85			Not Tested	
A36	Estane 5711	20	2	too viscous (#2)	15	30
	Vaseline	5				
	Dioctyl phthalate	2				
	Zelec UN	0.1	13			
	Paint Additive #7	0.05	11			
	Freon TF	25	13			
	Ethylene dichloride	45				

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Table 1 - Formulations (Cont.)

			Supplier	Viscosity seconds	Tack Time minutes	Dry Time minutes
A37	Estane 5711	10	2	too viscous (#2)	34	66
	Vaseline	2.5				
	Dioctyl phthalate	2				
	Zelec UN	0.05	13			
	Paint Additive #7	0.025	11			
	Trichloroethylene	35				
	Acetone	17.5				
A38	Parafilm	15	17	too viscous (#2)	4+ hrs.	---
	Day-Glo D13	1	9			
	Titania	5				
	Toluene	85				
A39	Estane 5711	20	2	too viscous (#2)	6	15
	Vaseline	5				
	Dioctyl phthalate	2				
	Methyl ethyl Ketone	60				
A40	Parafilm	10	17	too viscous (#2)	3.5+ hrs.	---
	Kraton 1101	5	21			
	Day-Glo D13	1	9			
	Titania	5				
	Toluene	85				
A41	Spraylat SC-1073	20	22	too viscous	10	31
	Day-Glo D13	0.5	9			
	Dioctyl phthalate	2		(#2)		
A42	Coverlac SC271	20	22	too viscous	12	19
	Dioctyl phthalate	2				
A43	Spraylat 1519A		22		Not Tested	
A44	Estane 5711	20	2			
	Vaseline	5			Not Tested	
	Dioctyl phthalate	2			Incompatible mixture	
	Methyl iso-Butyl Ketone	60				

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Table 1 - Formulas (Cont.)

			Supplier	Viscosity seconds	Tack Time minutes	Dry Time minutes
A45	Kraton 1101	5	21	too viscous (#2)	7	41
	Epolene X3259-11C	10	12			
	Trichloroethylene	75				
A46	Kraton 1101	10	21		Not Tested	
	Epolene X3259-11C	15	12			
	Trichloroethylene	75				
A47	Kraton 1101	10	21		Not Tested	
	Chlorowax 70	10	10			
	Trichloroethylene	70				
A48	Kraton 1101	8	21	too viscous (#2)	8	20
	Chlorowax 70	12	10			
	Trichloroethylene	70				
A49	Bakelite VYHH	10	23	40 (#2)	24	44
	Paraplex G-62	12.5	20			
	Chlorowax 70	12.5	10			
	Methy iso-Butyl Ketone	30				
	Toluene	30				
A50	Kraton 3202	8	21	25	12	26
	Chlorowax 70	12	10			
	Trichloroethylene	70				
A51	Kraton 3226	8	21	109	7	31
	Chlorowax 70	12	10			
	Trichloroethylene	70				
A52	Kraton 3202	10	21	too viscous (#2)	13	32
	Zelec UN	0.1	13			
	Vaseline	5				
	Paint Additive #7	0.07	11			
	Trichloroethylene	50				

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Table 1 - Formulas (Cont.)

			Supplier	Viscosity seconds	Tack Time minutes	Dry Time minutes
A53	Kraton 3226	10	21	too viscous (#2)	8	17
	Zelec UN	0.1	13			
	Vaseline	5				
	Paint Additive #7	0.07	11			
	Trichloroethylene	50				
A54	Kraton 1101	10	21	too viscous (#2)	6	11
	Epolene X3259-11C	10	12			
	Zelec UN	0.1	13			
	Trichloroethylene	75				
	NP Antidust	1	19			
A55	Kraton 1101	10	21		Not Tested	
	Epolene X3259-11C	15				
	Zelec UN	0.1	13			
	Trichloroethylene	75				
	NP Antidust	1				
A56	Kraton 1101	10	21	too viscous (#2)	6	13
	Chlorowax 70	10	10			
	Zelec UN	0.1	13			
	Trichloroethylene	70				
	NP Antidust	1	19			
A57	Spraylat SC-1073	20	22	too viscous	29	54
	Dioctyl phthalate	2				
A58	Spraylat SC-1073	20	22	Not Tested	32	93
	Paraplex G-62	2	20			
A59	Spraylat SC-1073	20	22	Not Tested	19	87
	Hercoflex 150	2	16			

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Table 1 - Formulas (Cont.)

			Supplier	Viscosity seconds	Tack Time minutes	Dry Time minutes
A60	Spraylat SC-1073	20	22		Not Tested	
	Resoflex R-296	2	4			
A61	Spraylat SC-1073	20	22	Not Tested	26	71
	Benzoflex 2-45	4	24			
A62	Coverlac A1114	20	22		Not Tested	
	Dioctyl phthalate	1				
A63	Coverlac A1114	20	22	too viscous	15	29
	Paraplex G-62	1	20			
A64	Coverlac A1114	20	22	Not Tested	10	46
	Hercoflex 150	1	16			
A65	Coverlac A1114	20	22		Not Tested	
	Resoflex R-296	1	4			
A66	Coverlac A1114	20	22		Not Tested	
	Benzoflex 2-45	1	24			
A67	Kraton 1101	10	21	too viscous (#2)	2	5
	Epolene X3259-11B	10	12			
	Zelec UN	0.1	13			
	NP Antidust	1	19			
	Trichloroethylene	105				
A68	Epolene X3259-11B	20	12		Not Tested	
	Zelec UN	0.1	13			
	NP Antidust	1	19			
	Trichloro ethylene	100				

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Table 1 - Formulas (Cont.)

			Supplier	Viscosity seconds	Tack Time minutes	Dry Time minutes
A69	Spraylat 1073	20	22	too viscous	13	38
	Benzoflex 2-45	2	24			
A70	Kraton 3202	10	21	167 (#2)	7	22
	Chlorowax 70	10	10			
	Trichloroethylene	70				
A71	Kraton 3226	10	21	too viscous (#2)	7	18
	Chlorowax 70	10	10			
	Trichloroethylene	70				
A72	Coverlac A1114	20	22	Not Tested	8	20
	Paraplex G-62	2	20			
A73	Coverlac A1114	20	22	too viscous	8	29
	Resoflex R-296	2	4			
A74	Coverlac A1114	20	22	Not Tested	9	24
	Paraplex G-62	3	20			
A75	Bakelite VYHH	10	23	75	Not Tested	
	Paraplex G-62	12.5	20			
	Chlorowax 40	12.5	10			
	Methyl isobutyl Ketone	30				
	Toluene	30				
A76	Coverlac A2114		22		Not Tested	
A77	Kraton 1101	8	21		Not Tested	
	Chlorowax 70	12	10			
	Zelec UN	0.2	13			
	NP Antidust	1	19			
	Trichloroethylene	70				
	Carbon black	2				

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Table 1 - Formulas (Cont.)

			Supplier	Viscosity seconds	Tack Time minutes	Dry Time minutes
A78	Coverlac A2114	20	22		Not Tested	
	Carbon black	2				
A79	Carbon black	2			Not Tested	
	Coverlac A2114	20	22			
	Paraplex G-62	1	20			
A80	Coverlac A2114	20	22		Not Tested	
	Resoflex R-296	2	4			
A81	Coverlac A2114	20	22	349 (#4)	Not Tested	
	Dioctyl phthalate	1				
A82	Coverlac A2114	20	22	too viscous	Not Tested	
	Benzoflex 2-45	1	24			
A83	Kraton 1101	8	21	too viscous (#4)	Not Tested	
	Chlorowax 70	12	10			
	Paraplex G-62	4	20			
	Trichloroethylene	70				
A84	Kraton 1101	8	21	too viscous (#4)	Not Tested	
	Chlorowax 70	12	10			
	Paraplex G-62	8	20			
	Trichloroethylene	70				
A85	Kraton 1101	8	21	too viscous (#4)	Not Tested	
	Chlorowax 70	12	10			
	Chlorowax 40	8	10			
	Trichloroethylene	70				

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Table 1 - Formulas (Cont.)

			Supplier	Viscosity seconds	Tack Time minutes	Dry Time minutes
A86	Kraton 1101	8	21		Not Tested	
	Chlorowax 70	12	10			
	Vaseline	8				
	Trichloroethylene	70				
A87	Kraton 1101	8	21		Not Tested	
	Chlorowax 70	12	10			
	Silicone grease	8	11			
	Trichloroethylene	70				
A88	Coverlac A2114	20	22	too viscous	Not Tested	
	Paraplex G-62	2	20	(#4)		
	Carbon black	2				
A89	Coverlac A2114	20	22	too viscous	Not Tested	
	Paraplex G-62	3	20	(#4)		
	Carbon black	2				
A90	Kraton 3202	8	21	30	Not Tested	
	Chlorowax 70	12	10	(#4)		
	Zelec UN	0.2	13			
	NP Antidust	1	19			
	Trichloroethylene	50				
	Sudan Red	0.2	7			
A91	Kraton 3226	8	21	28	Not Tested	
	Chlorowax 70	12	10	(#4)		
	Zelec UN	0.2	13			
	NP Antidust	1	19			
	Trichloroethylene	50				
	Sudan red	0.2	7			
A92	Kraton 1101	8	21	340	Not Tested	
	Chlorowax 70	12	10	(#4)		
	Chlorowax 40	8	10			
	Zelec UN	0.3	13			
	NP Antidust	1	19			
	Trichloroethylene	50				
	Sudan red	0.2	7			

Table 1 - Formulas (Cont.)

			Supplier	Viscosity seconds	Tack Time minutes	Dry Time minutes
A93	Kraton 1101	8	21	312	Not Tested	
	Kraton 3202	1	21	(#4)		
	Chlorowax 70	12	10			
	Chlorowax 40	8	10			
	Zelec UN	0.3	13			
	NP Antidust	1	19			
	Trichloroeth-ylene	50				
	Sudan red	0.2	7			
A94	Kraton 1101	8	21	too viscous (#4)	Not Tested	
	Kraton 3226	1	21			
	Chlorowax 70	12	10			
	Chlorowax 40	8	10			
	Zelec UN	0.3	13			
	NP Antidust	1	19			
	Trichloroeth-ylene	50				
	Sudan red	0.2	7			
A95	Kraton 1101	8	21	too viscous (#4)	Not Tested	
	Bakelite VYHH	1	23			
	Chlorowax 70	12	10			
	Chlorowax 40	8	10			
	Zelec UN	0.3	13			
	NP Antidust	1	19			
	Trichloroeth-ylene	50				
	Sudan red	0.2	7			
A96	Bakelite VYHH	10	23	61	Not Tested	
	Paraplex G-62	12.5	20	(#4)		
	Chlorowax 40	12.5	10			
	Chlorowax 70	5	10			
	Methyl iso-Butyl Ketone	25				
	Toluene	25				
	Sudan red	0.3	7			

Table 1 - Formulas (Cont.)

			Supplier	Viscosity seconds	Tack Time minutes	Dry Time minutes
A97	Bakelite VYHH	10	23	50	Not Tested	
	Paraplex G-62	15	20	(#4)		
	Chlorowax 40	15	10			
	Methyl iso-Butyl Ketone	25				
	Toluene	25				
	Sudan red	0.3	7			
A98	Bakelite VYHH	10	23		Not Tested	
	Paraplex G-62	12.5	20			
	Chlorowax 40	12.5	10			
	Methyl iso-Butyl Ketone	25				
	Toluene	25				
	Parafilm	5	17			
	Sudan red	0.3	7			
A99	Bakelite VYHH	10	23	too	Not Tested	
	Paraplex G-62	12.5	20	viscous		
	Chlorowax 40	12.5	10	(#4)		
	Methyl iso-Butyl Ketone	25				
	Toluene	25				
	Epolene 3259-11C	5	12			
	Sudan red	0.3	7			
A100	Bakelite VYHH	10	23	59	Not Tested	
	Paraplex G-62	12.5	20	(#4)		
	Chlorowax 40	7.5	10			
	Chlorowax 70	10	10			
	Methyl iso-Butyl Ketone	25				
	Toluene	25				
	Sudan red	0.2	7			
A101	Bakelite VYHH	10	23		Not Tested	
	Paraplex G-62	12.5	20			
	Chlorowax 70	17.5	10			
	Methyl iso-Butyl Ketone	30				
	Toluene	30				
	Sudan red	0.2	7			

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Table 1 - Formulas (Cont.)

			Supplier	Viscosity seconds	Tack Time minutes	Dry Time minutes
A102	Kraton 3202	8	21	33	7	20
	Chorowax 70	12	10	(#4)		
	Chlorowax 40	8	10			
	Zelec UN	0.2	13			
	NP Antidust	1	19			
	Trichloroeth-ylene	50				
	Sudan red	0.2	7			
A103	Kraton 3226	8	21	23	7	20
	Chlorowax 70	12	10	(#4)		
	Chlorowax 40	8	10			
	Zelec UN	0.2	13			
	NP Antidust	1	19			
	Trichloroeth-ylene	50				
	Sudan red	0.2	7			
A104	Kraton 1101	4	21	109	7	20
	Kraton 3202	4	21	(#4)		
	Chlorowax 70	12	10			
	Chlorowax 40	8	10			
	Zelec UN	0.2	13			
	NP Antidust	1	19			
	Trichloroeth-ylene	50				
	Sudan red	0.2	7			
A105	Kraton 1101	4	21	88	7	20
	Kraton 3226	4	21	(#4)		
	Chlorowax 70	12	10			
	Chlorowax 40	8	10			
	Zelec UN	0.2	13			
	NP Antidust	1	19			
	Trichloroeth-	50				
	Sudan red	0.2	7			
A106	Kraton 3202	8	21	50	7	20
	Chlorowax 70	12	10	(#4)		
	Chlorowax 40	8	10			
	Zelec UN	0.4	13			
	NP Antidust	1	19			
	Trichloroeth-ylene	50				
	Sudan red	0.2	7			

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Table 1 - Formulas (Cont.)

			Supplier	Viscosity seconds	Tack Time minutes	Dry Time minutes
A107	Kraton 3202	8	21	149	7	30
	Chlorowax 70	12	10	(#4)		
	Chlorowax 40	8	10			
	Zelec UN	0.6	13			
	NP Antidust	1	19			
	Trichloroethylene	50				
	Sudan red	0.2	7			
A108	Bakelite VYHH	10	23	too	7	30
	Kraton 3202	5	21	viscous		
	Chlorowax 70	20	10	(#4)		
	Chlorowax 40	5	10			
	Paraplex G-62	12	20			
	Paint Additive #7	0.1	11			
	Zelec UN	0.3	13			
	NP Antidust	1	19			
	Methyl iso-Butyl Ketone	30				
	Xylene	40				
	Sudan red	0.3	7			
A109	Bakelite VYHH	10	23	50	7	30
	Kraton 3226	5	21	(#4)		
	Chlorowax 70	20	10			
	Chlorowax 40	5	10			
	Paraplex G-62	12	20			
	Paint Additive #7	0.1	11			
	Zelec UN	0.3	13			
	NP Antidust	1	19			
	Methyl iso-Butyl Ketone	30				
	Xylene	40				
	Sudan red	0.3	7			

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Table 1 - Formulas (Cont.)

			Supplier	Viscosity seconds	Tack Time minutes	Dry Time minutes
A110	Kraton 3226	8	21	22 (#4)	3	5
	Chlorowax 70	12	10			
	Zelec UN	0.4	13			
	NP Antidust	1	19			
	Sudan red	0.2	7			
	Trichloroethylene	50				
A111	Parafilm	30	17	too viscous (#4)	Not Tested	
	Trichloroethylene	150				
	Water	100				
	Barak	1	13			
A112	Parafilm	18	17		Not Tested	
	Trichloroethylene	82				
A113	Parafilm	10	17	45 (#4)	Not Tested	
	Toluene	90				
A114	Kraton 1101	6	21	345 (#4)	3	5
	Kraton 3226	2	21			
	Chlorowax 70	8	10			
	Chlorowax 40	8	10			
	Zelec UN	0.4	13			
	Trichloroethylene	40				
	Sudan red	0.2	7			
A115	Kraton 1101	5	21	147 (#4)	3	15
	Kraton 3226	3	21			
	Chlorowax 70	8	10			
	Chlorowax 40	8	10			
	Zelec UN	0.4	13			
	Trichloroethylene	40				
	Sudan red	0.2	7			

Table 1 - Formulas (Cont.)

			Supplier	Viscosity seconds	Tack Time minutes	Dry Time minutes
A116	Kraton 1101	6	21		Not Tested	
	Bakelite VYHH	4	23			
	Chlorowax 70	8	10		Incompatible mixture	
	Chlorowax 40	12	10			
	Zelec UN	0.4	13			
	Trichloroethylene	50				
	Sudan red	0.2	7			
A117	Kraton 1101	4	21	105 (#4)	5	15
	Kraton 3226	4	21			
	Chlorowax 70	12	10			
	Chlorowax 40	8	10			
	Zelec UN	0.4	13			
	Trichloroethylene	50				
	Sudan red	0.2	7			
A118	Kraton 1101	4	21	78 (#4)	5	15
	Kraton 3226	4	21			
	Chlorowax 70	12	10			
	Chlorowax 40	8	10			
	Zelec UN	0.2	13			
	NP Antidust	0.5	19			
	Trichloroethylene	50				
	Sudan red	0.2	7			
A119	Butyl TC-49	38	8			
	Trichloroethylene	100				
A120	Kraton 3226	4	21			
	Butyl TC-49	10	8		Not Tested	
	Chlorowax 70	12	10		Incompatible mixture	
	Chlorowax 40	8	10			
	Zelec UN	0.3	13			
	NP Antidust	1	19			
	Day-Glo AX15-5	0.5	9			
	Trichloroethylene	50				

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Table 1 - Formulas (Cont.)

			Supplier	Viscosity seconds	Tack Time minutes	Dry Time minutes
A121	Kraton 3226	4	21			
	Butyl TC-49	10	8		Not Tested	
	Chlorowax 70	12	10		Incompatible mixture	
	Chlorowax 40	8	10			
	Zelec UN	0.2	13			
	NP Antidust	1	19			
	TiO_2	0.5				
	Trichloroethylene	50				
A122	Kraton 3226	4	21		Not Tested	
	Butyl TC-49	5	8		Incompatible mixture	
	Paraplex G-62	20	20			
	TiO_2	0.5				
	Trichloroethylene	30				
A123	Kraton 3226	4	21		Not Tested	
	Butyl TC-49	5	8		Incompatible mixture	
	Actinol EPG	3	1			
	TiO_2	0.5				
	Trichloroethylene	40				
A124	Kraton 3226	4	21		Not Tested	
	Butyl TC-49	5	8		Incompatible mixture	
	Titania	0.5				
	Trichloroethylene	40				
	Benzoflex	3	24			
A125	Kraton 3226	4	21		Not Tested	
	Butyl TC-49	5	8		Incompatible mixture	
	Titania	0.5				
	Trichloroethylene	40				
	Hercoflex	3	16			

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Table 1 - Formulas (Cont.)

			Supplier	Viscosity seconds	Tack Time minutes	Dry Time minutes
A126	Kraton 3226	4	21		Not Tested	
	Butyl TC-49	5	8		Incompatible mixture	
	Titania	0.5				
	Trichloroethylene	40				
	Resoflex	4	4			
A127	Kraton 1101	4	21			
	Kraton 3226	4	21			
	Chlorowax 70	12	10		Not Tested	
	Chlorowax 40	8	10			
	Zelec UN	0.2	13			
	NP Antidust	1	19			
	Day-Glo AX15-5	0.5	9			
	Toluene	50				
A128	Kraton 1101	4	21			
	Kraton 3226	4	21			
	Chlorowax 70	12	10		Not Tested	
	Chlorowax 40	8	10			
	Zelec UN	0.2	13			
	NP Antidust	1	19			
	Day-Glo AX15-5	0.5	9			
	Toluene	50				
A129	Kraton 1101	4	21			
	Kraton 3226	4	21			
	Chlorowax 70	12	10		Not Tested	
	Chlorowax 40	8	10			
	Zelec UN	0.2	13			
	NP Antidust	1	19			
	Titania	0.5				
	Trichloroethylene	50				

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Table 1 - Formulas (Cont.)

			Supplier	Viscosity seconds	Tack Time minutes	Dry Time minutes
A130	Kraton 1101	4	21	92	5	210
	Kraton 3226	4	21			
	Chlorowax 70	12	10			
	Chlorowax 40	8	10			
	Zelec UN	0.2	13			
	NP Antidust	1	19			
	Titania	0.5				
	Day-Glo AX15-5	0.5	9			
	Toluene	25				
A131	Kraton 1101	4	21		Not Tested	
	Kraton 3226	4	21			
	Chlorowax 70	12	10			
	Chlorowax 40	8	10			
	Zelec UN	0.2	13			
	NP Antidust	1	19			
	Trichloroethylene	50				
	Sudan red	0.2	7			
	Freon 12	81.3	13			
A132	Kraton 1101	4	21		Not Tested	
	Kraton 3226	4	21			
	Chlorowax 70	12	10			
	Chlorowax 40	8	10			
	Zelec UN	0.2	13			
	NP Antidust	1	19			
	Trichloroethylene	80				
	Sudan red	0.2	7			
	Freon 12	90.6	13			
A133	Kraton 1101	4	21		Not Tested	
	Kraton 3226	4	21			
	Chlorowax 70	12	10			
	Chlorowax 40	8	10			
	Zelec UN	0.2	13			
	NP Antidust	1	19			
	Titania	0.5				
	Day-Glo AX15-5	0.5	9			
	Toluene	45				
	Freon 12	50	13			

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Table 1 - Formulas (Cont.)

			Supplier	Viscosity seconds	Tack Time minutes	Dry Time minutes
A134	Kraton 1101	4	21		Not Tested	
	Kraton 3226	4	21			
	Chlorowax 70	12	10			
	Chlorowax 40	8	10			
	Zelec UN	0.2	13			
	NP Antidust	1	19			
	Trichloroethylene	75				
	Sudan red	0.2	7			
	Freon 12	62	13			
A135	Kraton 1101	4	21		Not Tested	
	Kraton 3226	4	21			
	Chlorowax 70	12	10			
	Chlorowax 40	8	10			
	Zelec UN	0.2	13			
	NP Antidust	1	19			
	Titania	0.5				
	Day-Glo AX15-5	0.5	9			
	Toluene	45				
	Freon 12	38	13			
	Modaflow	2	18			
A136	Kraton 1101	4	21		Not Tested	
	Kraton 3226	4	21			
	Chlorowax 70	12	10			
	Chlorowax 40	8	10			
	Zelec UN	0.2	13			
	NP Antidust	1	19			
	Trichloroethylene	75				
	Sudan red	0.2	7			

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Table 2 - Sources of Materials Used in Formulations

No.	Supplier
1	Arizona Chemical Company
2	B. F. Goodrich
3	Cabot Corporation, Oxides Division
4	Cambridge Industries Company
5	Central Scientific Company
6	Chas. Pfizer & Company, Inc., Williams Division
7	Chemical Sales Corporation
8	Chemical Sealing Corporation
9	Day-Glo Color Corporation
10	Diamond Shamrock Corporation
11	Dow Chemical Company
12	Eastman Chemical Products, Inc.
13	E. I. DuPont de Nemours & Company, Inc.
14	Firestone Synthetic Rubber & Latex Company
15	General Electric Company, Silicone Products Division
16	Hercules Powder Company
17	Marathon Products
18	Monsanto Company
19	National Polychemicals, Inc.
20	Rohm & Haas
21	Shell Chemical Company
22	Spraylat Corporation
23	Union Carbide Corporation, Chemicals & Plastics
24	Velsicol Chemical Corporation

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Table 3 - Release Materials

No.	Material	Source
B-1	Silicone self-vulcanizing tape 5-mil thick, 0.5 inch wide.	Permacil #P2650
B-2	Teflon tape. Ribbon dope thread sealant, 0.35 mil by 0.5 inch wide.	Permacel #P-412
B-3	Teflon telomer aerosol spray.	Ram #GS-3
B-4	Teflon telomer dispersion.	duPont Vydax AR
B-5	Kel-F grease, 37% in trichloroethylene.	3M Company
B-6	Silicone stopcock grease.	Dow-Corning Corporation
B-7	Reso-Part solution of polyvinyl alcohol	Plasticrafts, Inc. Denver, Colorado
B-8	Silicone rubber, RTV-E 50% solution in toluene with curing agent E	Dow-Corning Corporation
B-9	Parafilm, 5-mil, cut into tapes 1.5 cm wide	American Can Company Neenah, Wisconsin
B-10	Special Parafilm, 2-3 mil thick, cut into tapes 1.5 cm wide	American Can Company

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Table 4 - Adhesive Materials

No.	Material	Source
C-1	Rubber adhesive Scotch-Grip 847	3M Company
C-2	Rubber adhesive Scotch-Grip 4693	3M Company
C-3	Vinyl adhesive Scotch-Grip 2262	3M Company
C-4	Rubber adhesive Pliobond	Goodyear trademark, local hardware sales
C-5	Vinyl adhesive Penncraft Household Cement	J. C. Penney Co.
C-6	Double-tacky tape Scotch #665	3M Company
C-7	Pressure-sensitive latex adhesive Maniflex #1608	Manufacturers Chemical Co.

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Table 5 - Mechanical Properties of Coatings

	Stress @ 50% Strain kg/cm^2	% Set at 50% Elongation	Ultimate Tensile Strength kg/cm^2	Total Elongation %	Tear Strength	90° Peel Strength
A18	5.4	29.4	33.4	230	9.3	51.8
A19	29.2	60.6	77.4	560	50.7	---
A20	4.89	13.6	21.3	750	8.75	5.54
A21	4.79	48.9	22.8	200	6.91	64.3
A24	7.28	15.6	36.1	810	13.2	7.3
A26	12.0	18.6	59.6	740	16.7	178
A27	7.45	9.9	53.2	890	17.2	33.9
A28	45.0	57.2	104.0	490	53.1	1.79
A31	4.47	14	30.3	848	---	69.5
A33	25.8	71.0	79.5	140	20.6	13.7
A41	4.57	26.9	27.3	230	7.14	12.7
A42	---	Material was too sticky to prepare samples from				21.1
A43	---		To sticky for samples		---	19.2
A45	7.52	31.5	18.1	630	8.69	110.7
A46	---	---	Too sticky		---	86.9
A47	---	---	Too sticky		---	526.7
A48	28.1	37.0	125.0	710	44.9	---
A49	9.58	23	1.75	163	---	---
A50	29.8	84	37.5	240	27.0	357+
A51	29.0	78	35.9	430	28.1	357+
A52	1.46	To small to measure	8.2	630	3.29	5.3
A53	1.04	Too small to measure	7.69	690	3.16	5.4

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Table 5 - Mechanical Properties

	Stress @ 50% Strain kg/cm^2	% Set at 50% Elongation	Ultimate Tensile Strength kg/cm^2	Total Elongation %	Tear Strength	90° Peel Strength
A54	7.81	24.7	41.9	730	9.6	5.65
A55	4.96	28.5	13.4	600	6.65	9.76
A56	38.7	24.7	184.0	820	36.9	4.16
A57	3.57	31.2	73.0	310	6.52	12.4
A58	3.2	21.7	56.2	230	9.56	18.3
A59	3.26	25.4	51.5	300	7.78	13.9
A60	2.11	34.5	3.46	100	2.94	16.7
A61	2.8	22.9	33.7	370	5.86	did not peel
A62	1.51	65.4	1.51	150	2.20	did not peel
A63	14.3	36.7	36.7	930	8.50	did not peel
A64	2.37	76.1	2.37	100	1.07	did not peel
A65	9.22	33.8	49.9	910	12.2	did not peel
A66	1.66	59.2	1.66	120	1.74	did not peel
A67	11.9	25.4	37.9	740	12.8	17.9
A68	6.96	58.3	6.96	60	4.88	---
A69	2.82	24.7	12.7	190	5.36	20.6
A70	16.3	51.6	35.9	370	16.3	did not peel
A71	7.142	25.2	48.3	750	18.7	588
A72	3.92	38.9	6.61	590	5.15	5.54

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Table 5 - Mechanical Properties

	Stress @ 50% Strain Kg/cm^2	% Set at 50% Elongation	Ultimate Tensile Strength Kg/cm^2	Total Elongation %	Tear Strength	90° Peel Strength
A74	5.42	40.9	11.5	760	5.7	less than 1.8
A75	0.517	Too small to measure	5.48	250	0.982	3.12
A76	44.9	34.8	78.7	250	36.2	380
A77	25.6	31.4	31.1	460	22.8	2.32
A78	25.9	29.0	29.7	50	15.9	163
A79	8.85	34.3	7.38	less than 140	10.9	87.8
A80	11.0	25.0	19.4	390	16.9	205
A81	10.3	41.2	20.6	780	13.5	330
A82	12.5	48.5	13.7	790	11.6	107.7
A83	5.9	26.7	42.0	850	7.6	370
A84	4.32	24.2	32.0	860	6.06	107
A85	1.77	44.5	2.45	1400	1.95	101.2
A86	5.41	26.8	19.5	660	11.8	163
A87	18.3	31.3	19.4	200	17.7	did not peel
A88	12.5	32	13.3	790	8.0	31.0
A89	6.81	35	5.53	270	4.83	33.9
A90	26.6	78	26.8	210	23.6	41.0
A91	32.5	83	32.5	340	25.6	38.7
A92	1.48	39	1.74	1000+	2.18	31.6
A93	1.93	49	2.24	1000+	2.60	64.9
A94	1.91	44	2.10	1000+	2.24	108
A95	1.93	52	2.07	1000+	2.46	105

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Table 5 - Mechanical Properties

	Stress @ 50% Strain kg/cm^2	% Set at 50% Elongation	Ultimate Tensile Strength kg/cm^2	Total Elongation %	Tear Strength	90° Peel Strength
A96	1.21	66	4.16	230	1.30	1.7
A97	0.579	45	2.8	180	0.804	2.0
A99	0.701	41	1.32	170	0.953	9.8
A100	2.83	64	7.57	240	3.30	2.7
A101	2.58	86	25.8	120	13.3	17.7
A102	0.482	Too small to measure	0.804	260	0.601	17.4
A103	0.302	Too small to measure	0.501	260	0.518	11.2
A104	0.914	65	1.02	870	1.12	46.5
A105	0.930	58	1.05	770	1.29	23.9
A106	0.560	76	0.659	520	0.577	12.7
A107	0.649	81	0.649	250	0.482	35.2
A108	15.1	---	15.1	50	2.55	18.6
A109	25.9	---	25.9	50	3.29	8.8
A110	26.4	71	26.4	360	20.0	64.3
A117	1.28	56.8	1.54	1000+	1.89	57.2
A118	1.27	53.6	1.35	1000+	1.85	43.5
A130	1.35	53.0	1.61	860+	1.66	47.4
Parafilm	27.7	87	27.7	300	22.3	---

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Table 6 - Performance of Leak Detection Systems

Coating	Release	Adhesive	# Bubbles/# Leaks	Lift Distance mm	Comments
A48	B2	---	8/9	2-4	Brush application
A51	B2	---	1/7	2	" "
A55	---	C4	4/5	2-3	" "
A55	---	C6	3/5	2	" "
A56	B2	---	4/10	2-3	" "
A57	---	C3	5/5	1-3	" "
A57	---	C6	5/5	2-4	" "
A58	---	C3	5/5	1-3	" "
A58	---	C6	4/5	3-4	" "
A59	---	C7	0/2	---	" "
A59	---	C3	0/1	---	" "
A75	B3	---	6/9	3-13	" "
A81	B3	---	1/3	2	" "
A82	B7	---	1/4	1	" "
A83	B1	---	4/8	3-6	" "
A84	B8	---	4/8	2-6	" "
A85	B2	---	0/4	---	Aerosol
A85	---	---	0/5	---	"
A85	B3	---	2/2	2-3	Brush application
A85	B3	---	0/3	---	" "
A90	B6	---	0/1	---	" "
A90	B1	---	0/1	---	" "
A90	B9	---	2/2	2	" "
A90	---	---	0/0	---	" "

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Table 6 - Performance (Cont.)

Coating	Release	Adhesive	# Bubbles/# Leaks	Lift Distance mm	Comments
A91	B9	---	1/3	3	Brush application
A91	B2B	---	1/1	2	" "
A91	B1	---	2/2	1	" "
A91	B6	---	0/1	---	" "
A91	---	---	0/2	---	" "
A92	B2B	---	0/4	---	" "
A92	B1	---	2/4	10-13	" "
A92	B9	---	5/5	1-3	" "
A93	B2B	---	1/4	2	" "
A93	B1	---	1/4	10	" "
A94	B2B	---	0/3	---	" "
A94	B1	---	1/1	25	" "
A94	B3	---	0/0	---	" "
A94	B8	---	4/4	2-3	" "
A94	B9	---	0/0	---	" "
A94	B9	---	3/4	2-8	" "
A95	B3	---	0/0	---	" "
A95	B8	---	0/0	---	" "
A95	B9	---	0/0	---	" "
A96	---	C3	0/9	---	" "
A97	---	C3	0/0	---	" "
A97	B11	---	6/6	3-13	" "
A97	B6	---	0/0	---	" "
A99	---	C3	3/3	2-3	" "

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Table 6 - Performance (Cont.)

Coating	Release	Adhesive	# Bubbles/# Leaks	Lift Distance mm	Comments
A100	B2B	---	2/2	2	Brush application
A100	B1	---	2/2	1	" "
A100	B9	---	2/2	2	" "
A100	---	---	2/3	3	" "
A101	---	C3	1/1	2	" "
A101	B12	---	6/6	3-5	" "
A101	B7	---	1/1	2	" "
A102	B7	---	0/1	---	" "
A102	---	---	1/1	1	" "
A102	B2B	---	2/2	1	" "
A102	B1	---	0/2	---	" "
A102	B9	---	1/2	2	" "
A103	B7	---	0/2	---	" "
A103	---	---	0/1	---	" "
A103	B2B	---	0/2	---	" "
A103	B1	---	1/2	1	" "
A103	B9	---	0/3	---	" "
A104	B7	---	0/1	---	" "
A104	---	---	0/1	---	" "
A104	B2B	---	0/1	---	" "
A104	B1	---	0/1	---	" "
A104	B9	---	3/3	1	" "
A105	B9	---	3/3	3-35	" "

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Table 6 - Performance (Cont.)

Coating	Release	Adhesive	# Bubbles/# Leaks	Lift Distance mm	Comments
A105	---	---	0/1	---	Brush application
A105	B7	---	0/1	---	" "
A105	B2B	---	1/1	2	" "
A105	B1	---	2/2	2	" "
A105	B9	---	5/5	3-10	" "
A105	B13	---	0/7	---	" "
A105	B14	---	2/6	3	" "
A105	B15	---	0/3	---	" "
A105	B10	---	9/9	3-25	" "
A105	B10	---	9/10	3-6	" "
A106	B9	---	3/3	2-13	" "
A106	---	---	0/1	---	" "
A106	B7	---	0/1	---	" "
A106	B2B	---	2/2	1-2	" "
A106	B1	---	1/1	2	" "
A107	B9	---	0/1	---	" "
A107	---	---	0/1	---	" "
A107	B7	---	0/1	---	" "
A107	B2B	---	0/2	---	" "
A107	B1	---	2/2	2	" "
A110	B2B	---	3/3	1	" "
A110	B1	---	1/2	1	" "
A110	B7	---	0/2	---	" "
A110	B9	---	3/3	3-8	" "

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Table 6 - Performance (Cont.)

Coating	Release	Adhesive	# Bubbles/# Leaks	Lift Distance mm	Comments
A110	B9	---	7/9	2-5	Brush application
A112	B9	---	10/10	2	" "
A114	B3	---	0/2	---	" "
A114	---	---	0/1	---	" "
A114	B1	---	0/0	---	" "
A114	B9	---	0/2	---	" "
A115	B3	---	0/3	---	" "
A115	---	---	0/0	---	" "
A115	B1	---	2/2	13-35	" "
A115	B9	---	0/1	---	" "
A117	B10	---	3/5	2	" "
A118	B10	---	6/6	2-5	" "
A119	B10	---	5/7	1-13	" "
A130	B10	---	9/9	4-25	" "
A130	B10	---	9/9	3-35	" "
A130	B10	---	10/10	5-20	" "
A130	B10	---	7/7	3-25	" "
A131	B1	---	0/1	---	Aerosol
A131	---	---	0/1	---	"
A131	B3	---	0/1	---	"
A131	B10	---	0/1	---	"
A134	B10	---	7/9	3-25	"
A130	B10	---	8/8	3-25	Brush application
A130	B10	---	8/9	5-38	" "

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Table 6 - Performance (Cont.)

Coating	Release	Adhesive	# Bubbles/# Leaks	Lift Distance mm	Comments
A130	B10	---	9/9	3-51	Brush application
A130	B10	---	9/9	3-19	" "
A130	B10	---	10/10	3-51	" "
A130	B10	---	5/5	5-10	" "
A130	B10	---	6/6	5-19	" "
A130	B10	---	5/6	5-12	" "
A130	B10	---	10/10	3-25	" "

Total performance tests with recommended system:

A130	B10	---	105/107	3-51	Brush application

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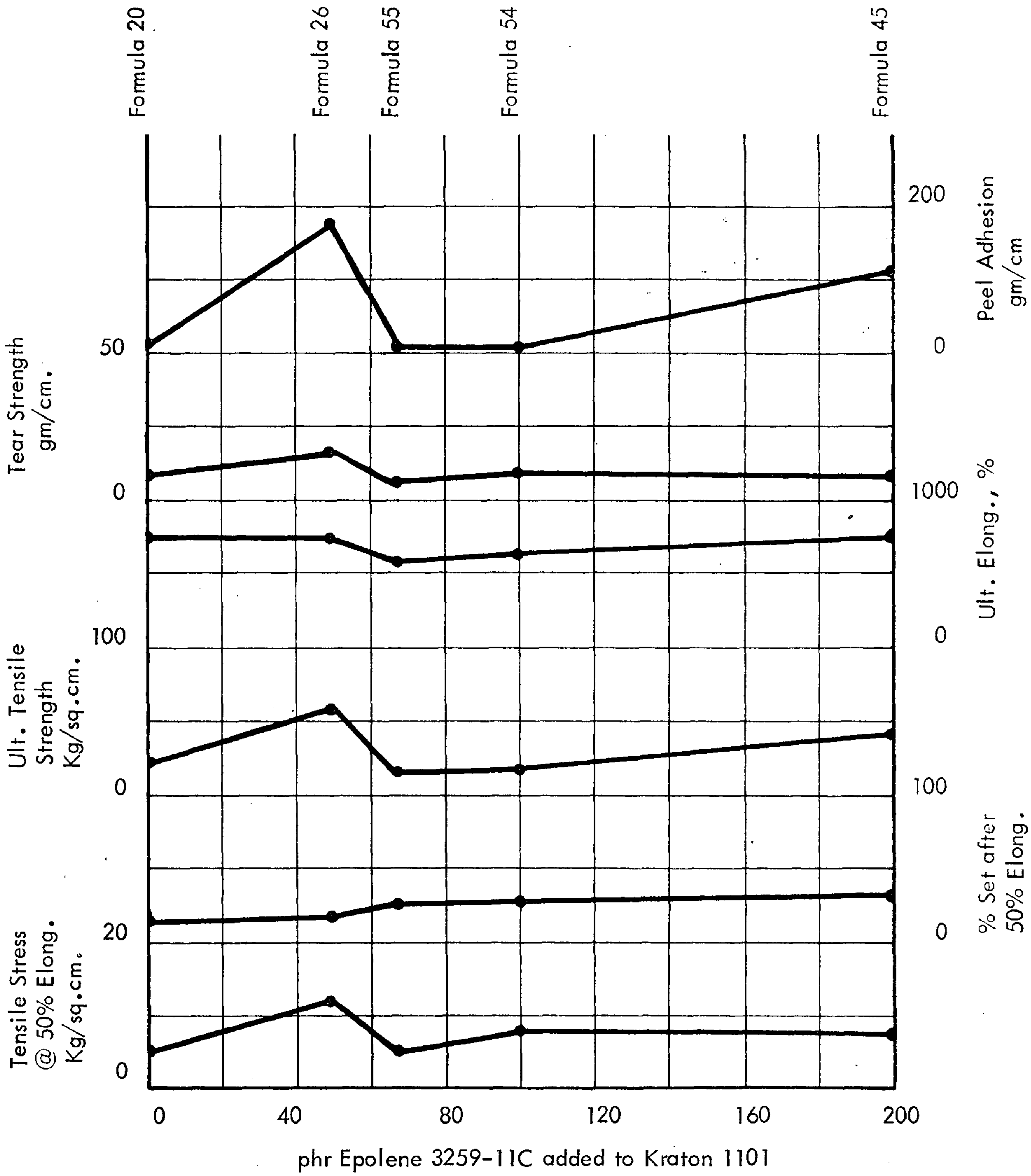

Figure 1 - Effects of Polypropylene Wax Added to Kraton Rubber Formulas

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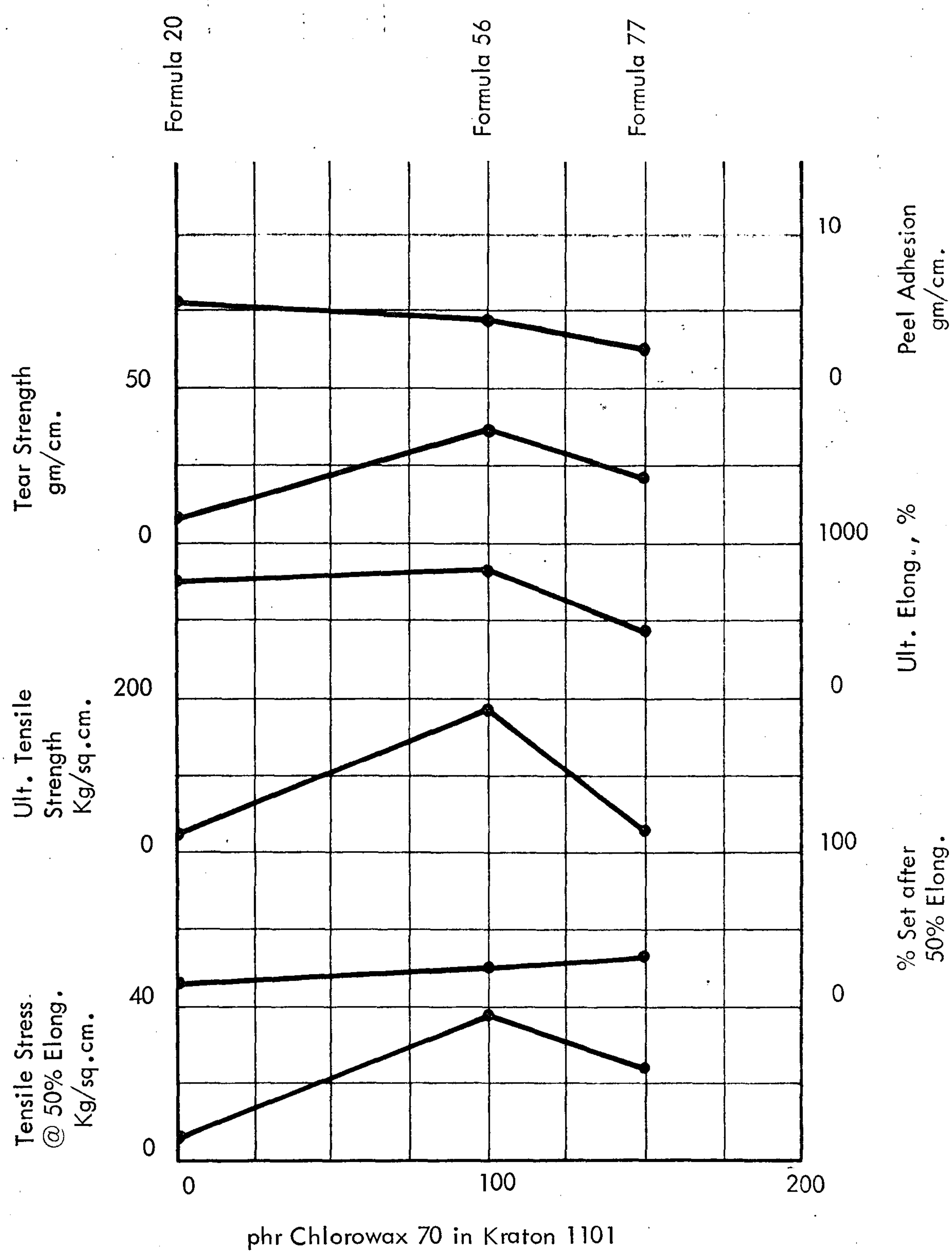

Figure 2 - Effects of Chlorowax 70 Added to Kraton 1101 Rubber

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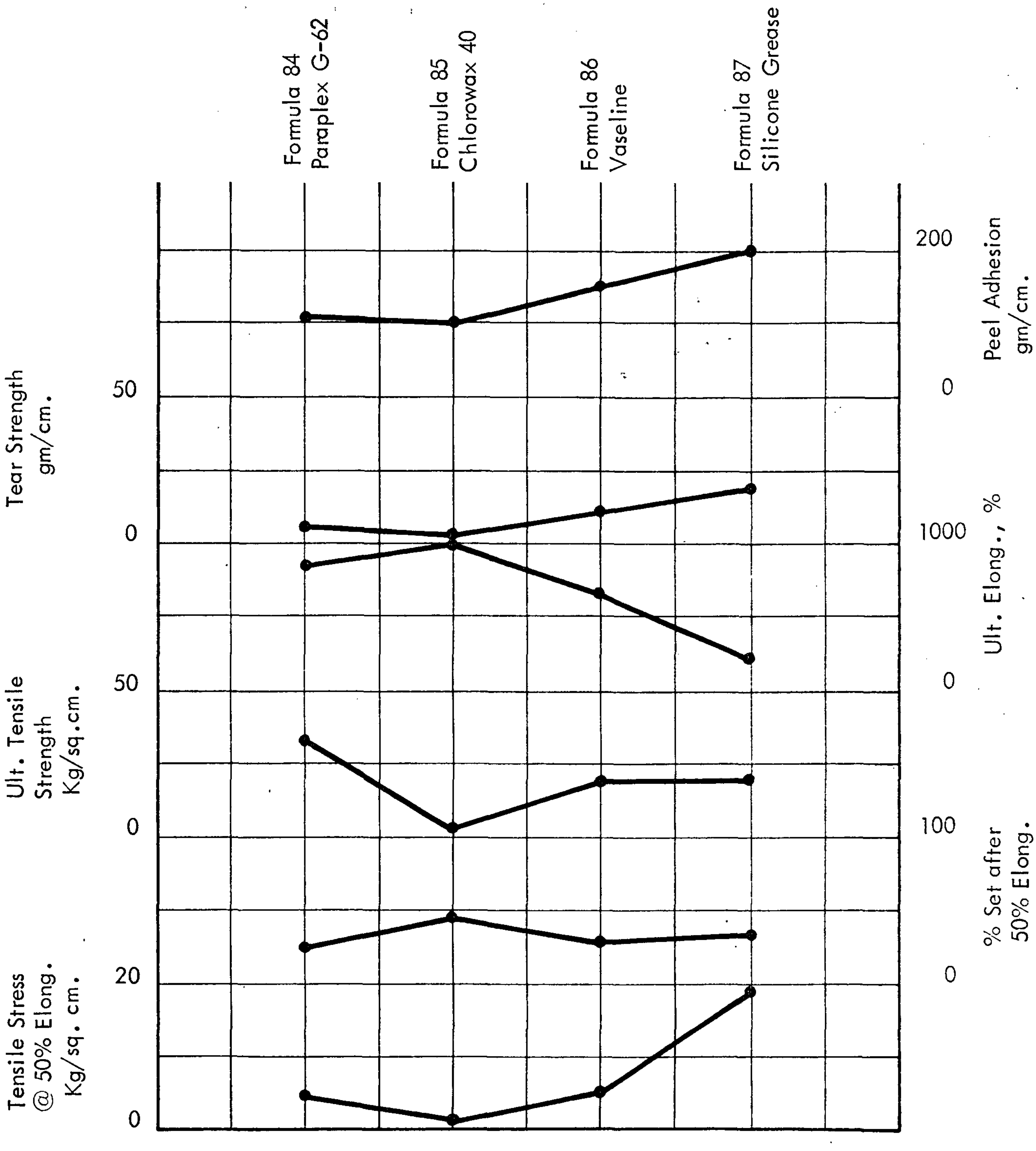

Figure 3 - Effects of Four Plasticizers Added to
Kraton 1101 Rubber with Chlorowax 70

54

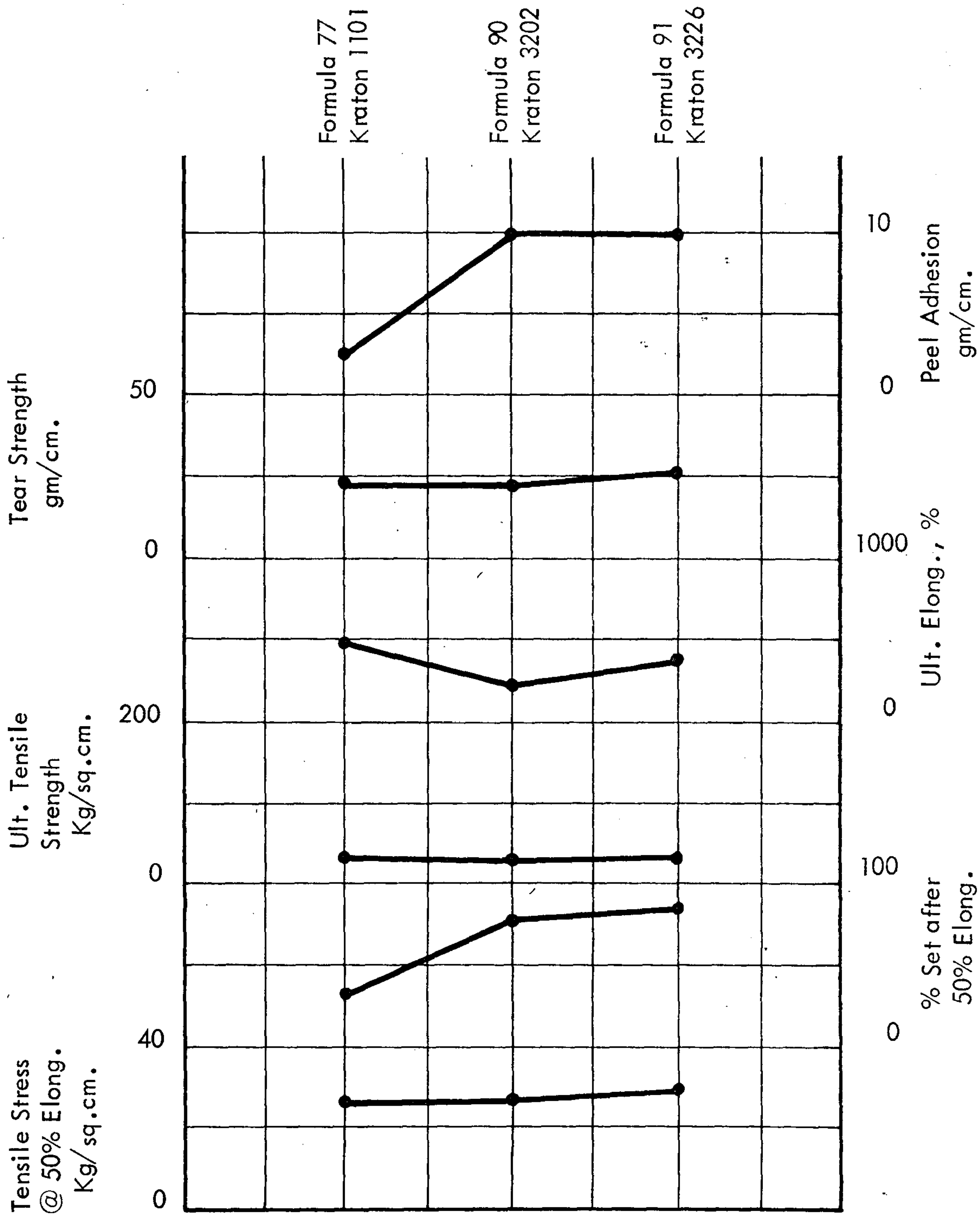

Figure 4 - Comparison of Three Different
Kraton Rubbers used with 150 phr
Chlorowax 70.

55

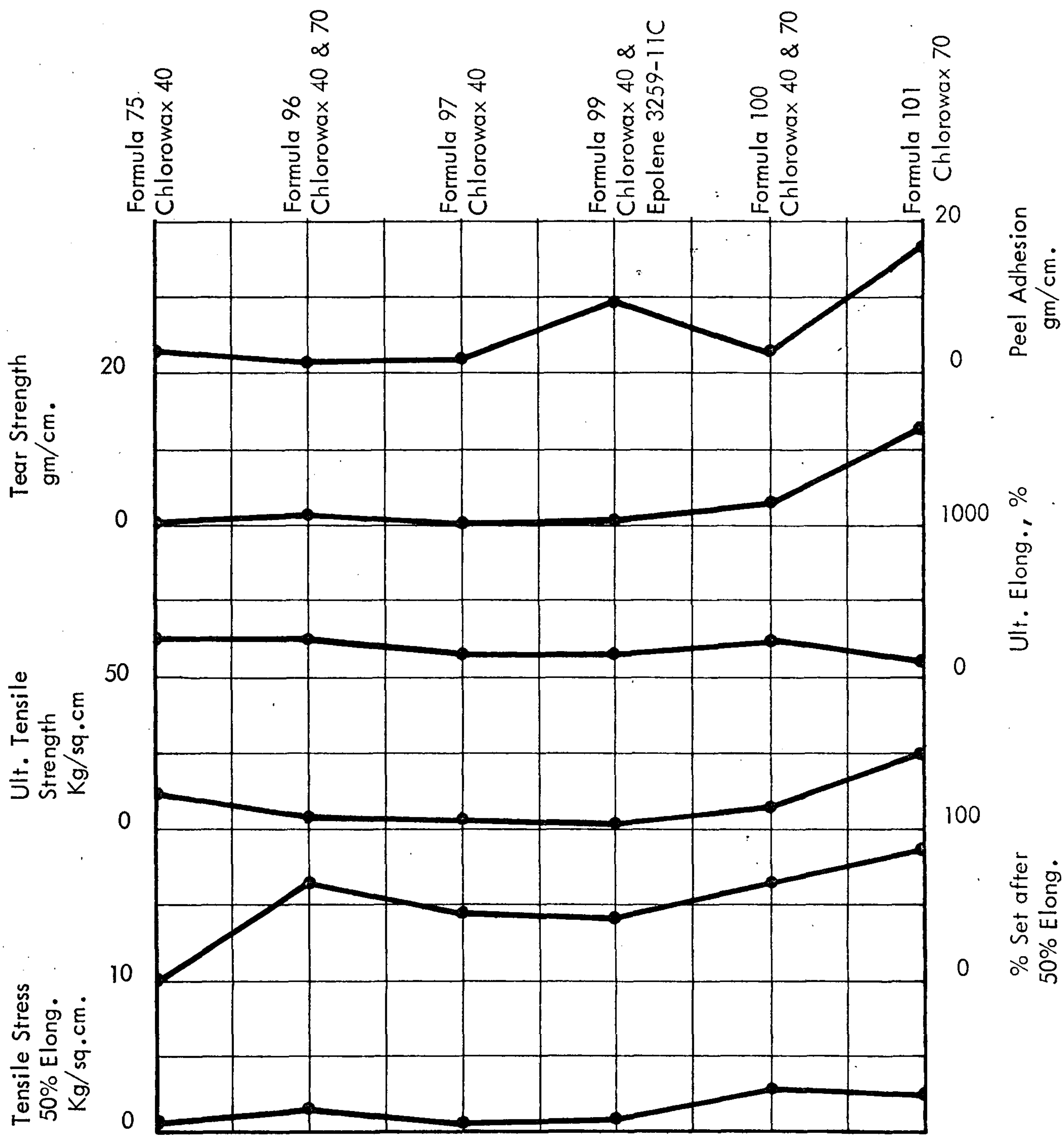

Figure 5 - Effects of Plasticizers and Waxes Added
to Vinyl Resin VYHH and Paraplex G-62

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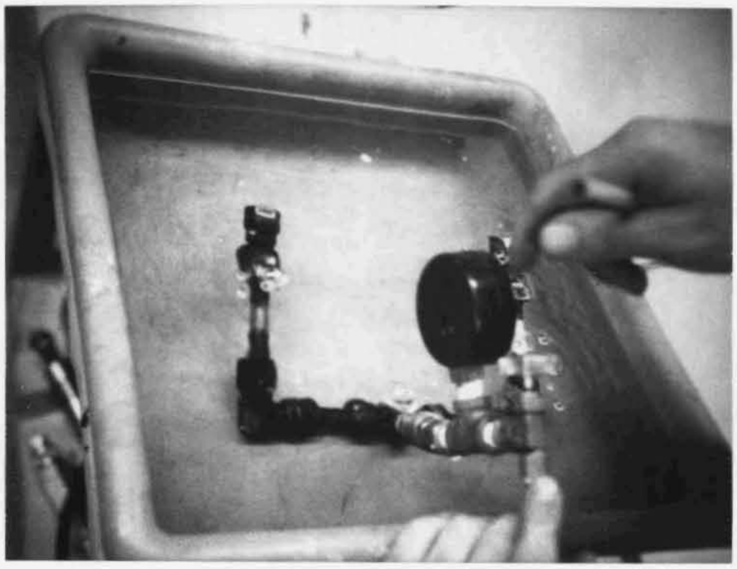

Figure 6 - Performance Evaluation of Leak Detection Systems under Water. Expanded coatings are readily discernible on two connectors.

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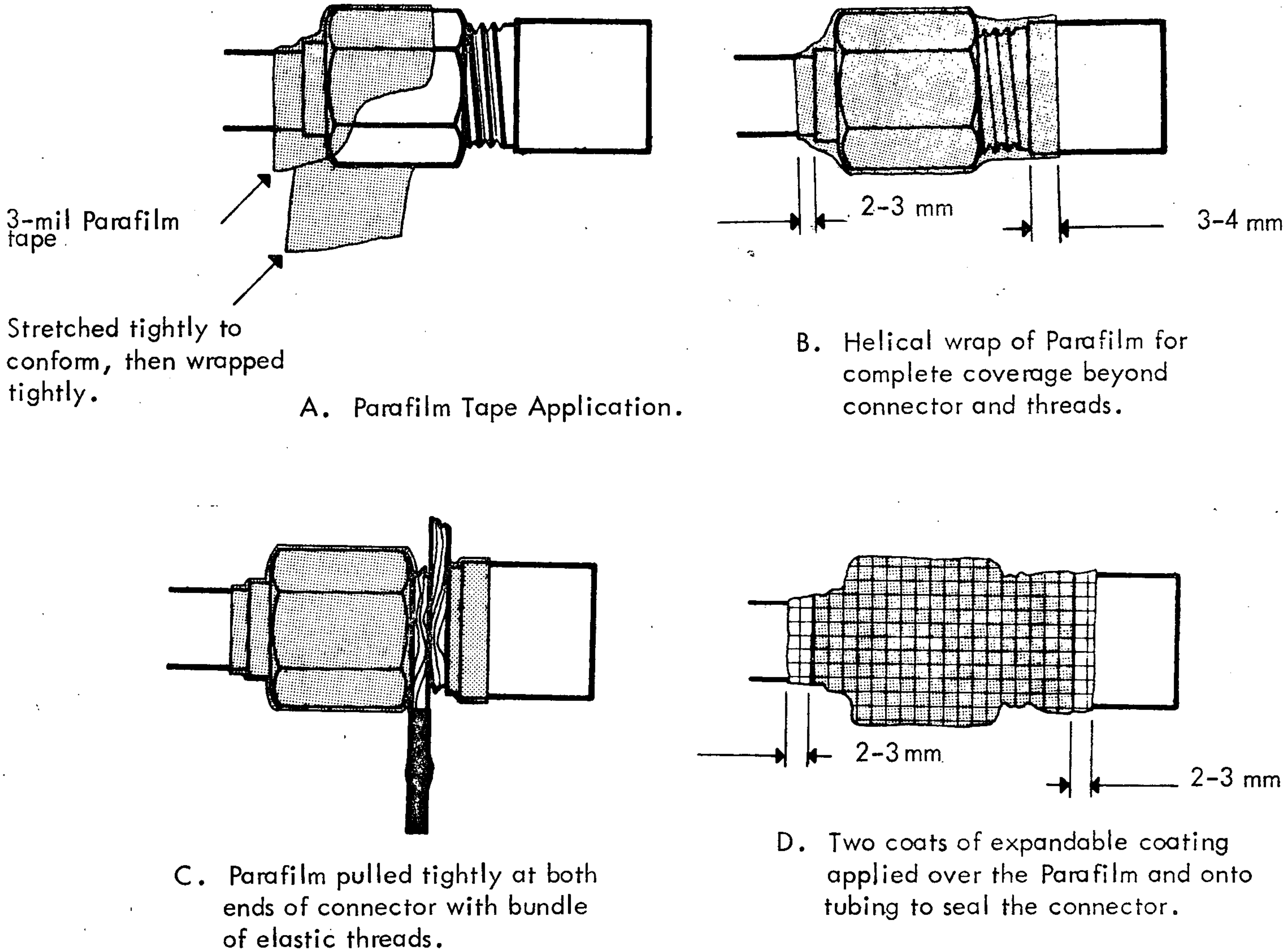

Figure 7 - Step-wise Application of Parafilm Release Tape and Expandable Coating for Leak Detection System.

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